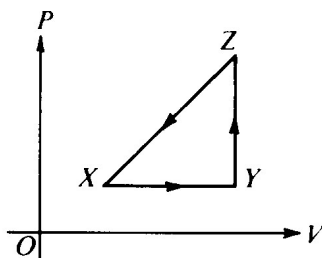


AP Physics Multiple Choice Practice – Thermodynamics

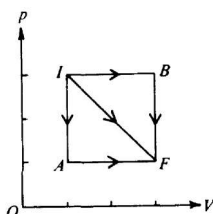
- An ideal gas is made up of N diatomic molecules, each of mass M . All of the following statements about this gas are true EXCEPT:
 - The temperature of the gas is proportional to the average translational kinetic energy of the molecules.
 - All of the molecules have the same speed.
 - The molecules make elastic collisions with each other and with the walls of the container.
 - The average number of collisions per unit time that the molecules make with the walls of the container depends on the temperature of the gas.

Questions 2-3



A thermodynamic system is taken from an initial state X along the path $XYZX$ as shown in the PV -diagram.

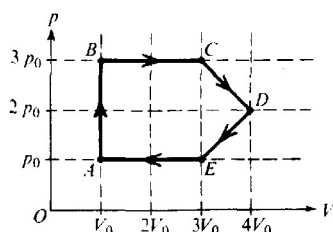
- For the process $X \rightarrow Y$, ΔU is greater than zero and
 - $Q < 0$ and $W = 0$
 - $Q < 0$ and $W > 0$
 - $Q > 0$ and $W < 0$
 - $Q > 0$ and $W > 0$
- For the process $Y \rightarrow Z$, Q is greater than zero and
 - $W < 0$ & $\Delta U = 0$
 - $W = 0$ & $\Delta U < 0$
 - $W = 0$ & $\Delta U > 0$
 - $W > 0$ & $\Delta U > 0$
- An ideal gas confined in a box initially has pressure p . If the absolute temperature of the gas is doubled and the volume of the box is quadrupled, the pressure is
 - $p/8$
 - $p/4$
 - $p/2$
 - $2p$
- An ideal gas in a closed container initially has volume V , pressure P , and Kelvin temperature T . If the temperature is changed to $3T$, which of the following pairs of pressure and volume values is possible?
 - $3P$ and V
 - $3P$ and $3V$
 - P and $V/3$
 - $P/3$ and V



- If three identical samples of an ideal gas are taken from initial state I to final state F along the paths IAF , IF , and IBF as shown in the pV -diagram above, which of the following must be true?
 - The heat absorbed by the gas is the same for all three paths.
 - The change in internal energy of the gas is the same for all three paths.
 - The expansion along path IF is adiabatic.
 - The expansion along path IF is isothermal.
- If the average kinetic energy of the molecules in an ideal gas at a temperature of 300 K is E , the average kinetic energy at a temperature of 600 K is
 - E
 - $\sqrt{2}E$
 - $2E$
 - $4E$

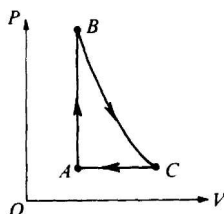
8. A metal rod of length L and cross-sectional area A connects two thermal reservoirs of temperatures T_1 and T_2 . The amount of heat transferred through the rod per unit time is directly proportional to
 (A) A and L (B) A and $1/L$ (C) $1/A$ and L (D) $1/A$ and $1/L$

Questions 9-10



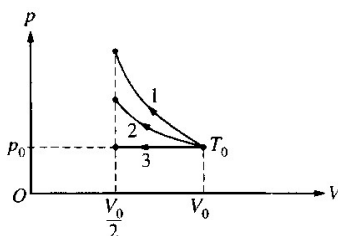
An ideal gas undergoes a cyclic process as shown on the graph above of pressure p versus volume V .

9. During which process is no work done on or by the gas?
 (A) AB (B) BC (C) CD (D) EA
10. At which point is the gas at its highest temperature?
 (A) A (B) B (C) C (D) D



11. Gas in a chamber passes through the cycle ABCA as shown in the diagram above. In the process AB, 12 joules of heat is transferred to the gas. In the process BC, no heat is exchanged with the gas. For the complete cycle ABCA, the work done by the gas is 8 joules. How much heat is added to or removed from the gas during process CA?
 (A) 20 J is removed. (B) 4 J is removed. (C) 4 J is added. (D) 20 J is added.
12. If the gas in a container absorbs 275 joules of heat, has 125 joules of work done on it, and then does 50 joules of work, what is the increase in the internal energy of the gas?
 (A) 450 J (B) 400 J (C) 350 J (D) 200 J

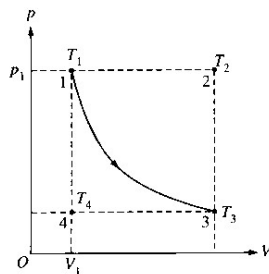
Questions 13-14



A certain quantity of an ideal gas initially at temperature T_0 , pressure p_0 , and volume V_0 is compressed to one-half its initial volume. As shown above, the process may be adiabatic (process 1), isothermal (process 2), or isobaric (process 3).

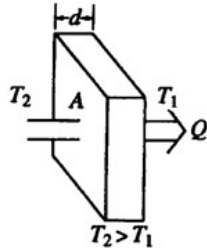
13. Which of the following is true of the mechanical work done on the gas?
 (A) It is greatest for process 1.
 (B) It is greatest for process 2.
 (C) It is greatest for process 3.
 (D) It is the same for all three processes.

14. Which of the following is true of the final temperature of this gas?
 (A) It is greatest for process 1. (B) It is greatest for process 2.
 (C) It is greatest for process 3. (D) It is the same for all three processes.
15. In a certain process, 400 J of heat is transferred to a system and the system simultaneously does 100 J of work. The change in internal energy of the system is
 (A) 500 J (B) 300 J (C) -100 J (D) -300 J

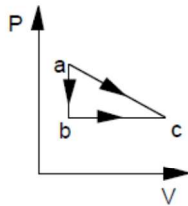


16. **Multiple Correct.** An ideal gas is initially in a state that corresponds to point 1 on the graph above, where it has pressure p_1 , volume V_1 , and temperature T_1 . The gas undergoes an isothermal process represented by the curve shown, which takes it to a final state 3 at temperature T_3 . If T_2 and T_4 are the temperatures the gas would have at points 2 and 4, respectively, which of the following relationships is true? Select two answers:
 (A) $T_1 < T_3$ (B) $T_1 < T_2$ (C) $T_1 = T_3$ (D) $T_1 = T_4$
17. The absolute temperature of a sample of monatomic ideal gas is doubled at constant volume. What effect, if any, does this have on the pressure and density of the sample of gas?
- | <u>Pressure</u> | <u>Density</u> |
|----------------------|------------------|
| (A) Remains the same | Remains the same |
| (B) Remains the same | Doubles |
| (C) Doubles | Remains the same |
| (D) Doubles | Doubles |
18. Which of the following statements is NOT a correct assumption of the classical model of an ideal gas?
 (A) The molecules are in random motion.
 (B) The volume of the molecules is negligible compared with the volume occupied by the gas.
 (C) The molecules obey Newton's laws of motion.
 (D) The collisions between molecules are inelastic.
19. A sample of an ideal gas is in a tank of constant volume. The sample absorbs heat energy so that its temperature changes from 300 K to 600 K. If v_1 is the average speed of the gas molecules before the absorption of heat and v_2 is their average speed after the absorption of heat, what is the ratio v_2/v_1 ?
 (A) 4 (B) 2 (C) $\sqrt{2}$ (D) 1/2
20. Two blocks of steel, the first of mass 1 kg and the second of mass 2 kg, are in thermal equilibrium with a third block of aluminum of mass 2 kg that has a temperature of 400 K. What are the respective temperatures of the first and second steel blocks?
 (A) 400 K and 200 K (B) 200 K and 400 K (C) 400 K and 400 K (D) 800 K and 400 K
21. An ideal gas may be taken from one state to another state with a different pressure, volume, and temperature along several different paths. Quantities that will always be the same for this process, regardless of which path is taken, include which of the following?
 I. The change in internal energy of the gas
 II. The heat exchanged between the gas and its surroundings
 III. The work done by the gas
 (A) I only (B) II only (C) I and III only (D) II and III only

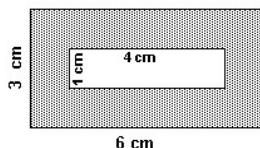
22. A square steel plate with sides of length 1.00 m has a hole in its center 0.100 m in diameter. If the entire plate is heated to such a temperature that its sides become 1.01 m long, the diameter of the hole will be
 (A) 0.090 m (B) 0.099 m (C) 0.101 m (D) 0.110 m
23. Which of the following will occur if the average speed of the gas molecules in a closed rigid container is increased?
 (A) The density of the gas will decrease. (B) The density of the gas will increase.
 (C) The pressure of the gas will increase. (D) The pressure of the gas will decrease.



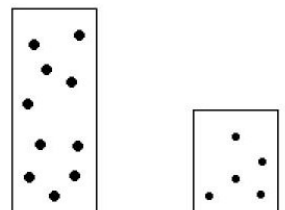
24. In time t , an amount of heat Q flows through the solid door of area A and thickness d represented above. The temperatures on each side of the door are T_2 and T_1 , respectively. Which of the following changes would be certain to decrease Q ?
 (A) Increasing A only (B) Decreasing d only
 (C) Increasing d and $T_2 - T_1$ only (D) Decreasing A and $T_2 - T_1$ only
25. A gas with a fixed number of molecules does 32 J of work on its surroundings, and 16 J of heat are transferred from the gas to the surroundings. What happens to the internal energy of the gas?
 (A) It decreases by 48 J. (B) It decreases by 16 J. (C) It increases by 16 J. (D) It increases by 48 J.
26. A mass m of helium gas is in a container of constant volume V . It is initially at pressure p and absolute (Kelvin) temperature T . Additional helium is added, bringing the total mass of helium gas to $3m$. After this addition, the temperature is found to be $2T$. What is the gas pressure?
 (A) $2/3 p$ (B) $3/2 p$ (C) $3 p$ (D) $6 p$



27. A gas can be taken from state a to c by two different reversible processes, $a \Rightarrow c$ or $a \Rightarrow b \Rightarrow c$. During the direct process $a \Rightarrow c$, 20.0 J of work are done by the system and 30.0 J of heat are added to the system. During the process $a \Rightarrow b \Rightarrow c$, 25.0 J of heat are added to the system. How much work is done by the system during $a \Rightarrow b \Rightarrow c$?
 (A) 5.0 J (B) 10.0 J (C) 15.0 J (D) 20.0 J
28. When an ideal gas is isothermally compressed:
 (A) thermal energy flows from the gas to the surroundings.
 (B) thermal energy flows from the surroundings to the gas.
 (C) no thermal energy enters or leaves the gas.
 (D) the temperature of the gas increases.
30. A 200 gram sample of copper is submerged in 100 grams of water until both the copper and water are at the same temperature. Which of the following statements would be true?
 (A) the molecules of the water and copper would have equal average speeds
 (B) the molecules of the water and copper would have equal average momenta
 (C) the molecules of the water and copper would have equal average kinetic energies
 (D) the water molecules would have twice the average speed of the copper molecules



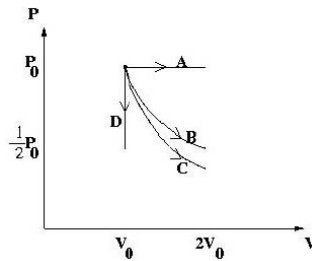
31. A rectangular piece of metal 3 cm high by 6 cm wide has a hole cut in its center 1 cm high by 4 cm wide as shown in the diagram at right. As the metal is warmed from 0°C to 100°C , what will happen to the dimensions of the hole?
- (A) both height and width will increase
 (B) both height and width will decrease
 (C) height will increase while width will decrease
 (D) height will decrease while width will increase
32. A gas is enclosed in a cylindrical piston. When the gas is heated from 0°C to 100°C , the piston is allowed to move to maintain a constant pressure. According to the Kinetic-Molecular Theory of Matter
- (A) the molecules continue to strike the sides of the container with the same energy
 (B) the number of molecules of gas must increase
 (C) the size of the individual molecules has increased
 (D) the average speed of the molecules has increased



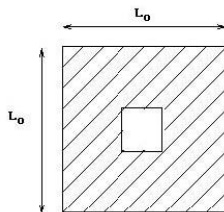
33. Two containers are filled with gases at the same temperature. In the container on the left is a gas of molar mass $2M$, volume $2V$, and number of moles $2n$. In the container on the right is a gas of molar mass M , volume V , and moles n . Which is most nearly the ratio of the pressure of the gas on the left to the pressure of the gas on the right?
- (A) 1:1 (B) 2:1 (C) 4:1 (D) 8:1
34. A fan blows the air and gives it kinetic energy. An hour after the fan has been turned off, what has happened to the kinetic energy of the air?
- (A) it turns into thermal energy (B) it turns into sound energy
 (C) it turns into potential energy (D) it turns into electrical energy
35. According to the kinetic theory of gases, when the absolute temperature of an ideal gas doubles, the average kinetic energy of the molecules of the gas
- (A) quadruples (B) doubles (C) is cut in half (D) is quartered
36. When gas escapes from a pressurized cylinder, the stream of gas feels cool. This is because
- (A) work is being done at the expense of thermal energy
 (B) of the convection inside the cylinder
 (C) pressurized cylinders are good thermal insulators
 (D) the moisture in the air condenses and cools
37. Two completely identical samples of the same ideal gas are in equal volume containers with the same pressure and temperature in containers labeled A and B. The gas in container A performs non-zero work W on the surroundings during an isobaric (constant pressure) process before the pressure is reduced isochorically (constant volume) to $\frac{1}{2}$ its initial amount. The gas in container B has its pressure reduced isochorically (constant volume) to $\frac{1}{2}$ its initial value and then the gas performs non-zero work W on the surroundings during an isobaric (constant pressure) process.

- After the processes are performed on the gases in containers A and B, which is at the higher temperature?
- (A) The gas in container A
 (B) The gas in container B
 (C) The value of the work W is necessary to answer this question.
 (D) The value of the work W is necessary, along with both the initial pressure and volume, in order to answer the question.

38. The volume of an ideal gas changes as the gas undergoes an isobaric (constant pressure) process starting from temperature 273°C and ending at 546°C . What is the ratio of the new volume of the gas to the old volume ($V_{\text{new}}/V_{\text{old}}$)?
- (A) $\frac{1}{2}$ (B) $\frac{2}{3}$ (C) $\frac{3}{2}$ (D) 2
39. A frozen hamburger in plastic needs to be thawed quickly. Which of the methods described provides the most rapid thawing of the burger?
- (A) Place the burger itself in a metal pan at room temperature.
 (B) Place the burger itself on the ceramic kitchen counter at room temperature.
 (C) Place the burger in its package on the kitchen counter at room temperature.
 (D) Place the burger in its package in a pot of non-boiling warm water.

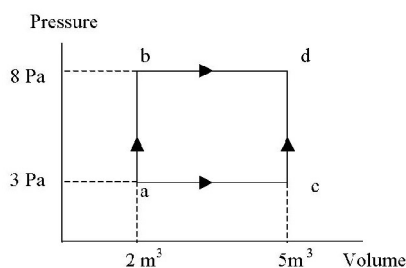


40. **Multiple Correct.** The PV diagram shows four different possible reversible processes performed on a monatomic ideal gas. Process A is isobaric (constant pressure). Process B is isothermal (constant temperature). Process C is adiabatic. Process D is isochoric (constant volume). For which processes does the temperature of the gas decrease? Select two answers:
- (A) Process A (B) Process B (C) Process C (D) Process D
41. A pure 4-mole sample of a newly discovered monatomic ideal gas is sitting in a container at equilibrium in a 20.0°C environment. According to the kinetic theory of gases, what is the average kinetic energy per molecule for this gas?
- (A) $4.14 \times 10^{-22}\text{ J}$ (B) $2.02 \times 10^{-21}\text{ J}$ (C) $6.07 \times 10^{-21}\text{ J}$
 (D) The molar mass of the gas is needed to answer this question.



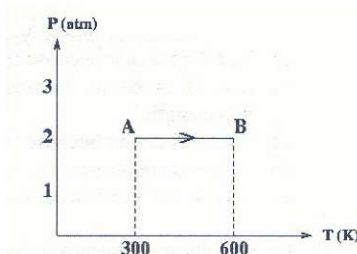
42. A uniform square piece of metal has initial side length L_0 . A square piece is cut out of the center of the metal. The temperature of the metal is now raised so that the side lengths are increased by 4%. What has happened to the area of the square piece cut out of the center of the metal?
- (A) It is increased by 8 % (B) It is increased by 4 % (C) It is decreased by 4 % (D) It is decreased by 8 %

43. A monatomic ideal gas at pressure $P = 10^5$ Pa is in a container of volume $V = 12 \text{ m}^3$ while at temperature $T = 50^\circ\text{C}$. How many molecules of gas are in the container?
 (A) 1.74×10^{27} (B) 2.69×10^{26} (C) 2888 (D) 447
44. Absolute zero is best described as that temperature at which
 (A) water freezes at standard pressure.
 (B) the molecules of a substance have a maximum kinetic energy.
 (C) the molecules of a substance have a maximum potential energy.
 (D) the molecules of a substance have minimum kinetic energy.

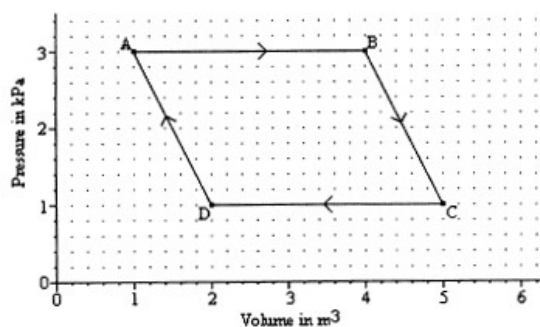


45. In the Pressure versus Volume graph shown, in the process of going from a to b 60 J of heat are added, and in the process of going from b to d 20 J of heat are added. In the process of going a to c to d, what is the total heat added?
 (A) 80 J (B) 65 J (C) 56 J (D) 47 J
46. Which is not true of an isochoric process on an enclosed ideal gas in which the pressure decreases?
 (A) The work done is zero. (B) The internal energy and temperature of the gas decreases.
 (C) The heat is zero. (D) The rms speed of the gas molecules decreases.
47. One mole of an ideal gas has a temperature of 100°C . If this gas fills the 10.0 m^3 volume of a closed container, what is the pressure of the gas?
 (A) 0.821 Pa (B) 3.06 Pa (C) 83.1 Pa (D) 310 Pa
48. An ideal gas is enclosed in a container. The volume of the container is reduced to half the original volume at constant temperature. According to kinetic theory, what is the best explanation for the increase in pressure created by the gas?
 (A) The average speed of the gas particles decreases, but they hit the container walls more frequently.
 (B) The average speed of the gas particles is unchanged, but they hit the container walls more frequently.
 (C) The average speed of the gas particles increases as does the frequency with which they hit the container walls.
 (D) The average speed of the gas particles increases, overcoming the decreased frequency that they hit the container walls.
49. A mole of a monatomic ideal gas has pressure P , volume V , and temperature T . Which of the following processes would result in the greatest amount of energy added to the gas from heat?
 (A) A process doubling the temperature at constant pressure.
 (B) An adiabatic expansion doubling the volume.
 (C) A process doubling the pressure at constant volume.
 (D) A process doubling the volume at constant temperature.
50. An ideal gas in a closed container of volume 6.0 L is at a temperature of 100°C . If the pressure of the gas is 2.5 atm , how many moles of gas are in the container?
 (A) 0.0048 (B) 0.018 (C) 0.49 (D) 1.83

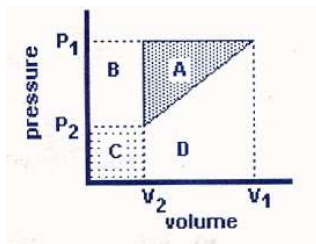
51. An ideal gas undergoes an isobaric expansion followed by an isochoric cooling. Which of the following statements *must* be true after the completion of these processes?
- (A) The final pressure is less than the original pressure.
 (B) The final volume is less than the original volume.
 (C) The final temperature is less than the original temperature.
 (D) The total quantity of heat, Q , associated with these processes is positive.



52. Two moles of a monatomic ideal gas undergoes the process from A to B, shown in the diagram above by the solid line. Using the sign convention that work is positive when surroundings do work on the system, how much work is done in the process AB?
- (A) 5000 J (B) 1200 J (C) -1200 J (D) -5000 J



53. A sample of gas is caused to go through the cycle shown in the pV diagram shown above. What is the net work done by the gas during the cycle?
- (A) 4,000 J (B) 6,000 J (C) 8,000 J (D) 12,000 J
54. A sample of an ideal monatomic gas is confined in a rigid 0.008 m^3 container. If 40 joules of heat energy were added to the sample, how much would the pressure increase?
- (A) 320 Pa (B) 1,600 Pa (C) 3,333 Pa (D) 5,000 Pa
55. Hydrogen gas (H_2) and oxygen gas (O_2) are in thermal equilibrium. How does the average speed of the hydrogen molecules compare to the average speed of oxygen molecules?
- (A) equal (B) 4 times greater (C) 8 times greater (D) 16 times greater
56. Hydrogen gas is contained in a rigid container. A second rigid container of equal volume contains oxygen gas. If the average rms velocities of the molecules in each container is the same, which of the following *must* be true?
- (A) The oxygen gas would apply the greater pressure.
 (B) The temperature of both gasses would be identical.
 (C) There would be an equal pressure in each container.
 (D) The oxygen gas would have the higher temperature.
57. A mole of ideal gas at STP is heated in an insulated constant volume container until the average velocity of its molecules doubled. Its pressure would therefore increase by what factor?
- (A) 0.5 (B) 1 (C) 2 (D) 4



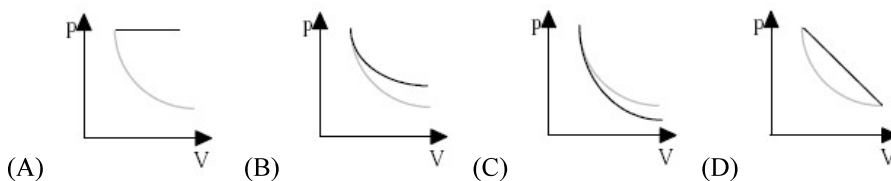
58. **Multiple Correct.** A sample of gas was first compressed from V_1 to V_2 at a constant pressure of P_1 . The sample was then cooled so that the pressure went from P_1 to P_2 while the volume remained constant at V_2 . Finally the sample was allowed to expand from V_2 back to V_1 while the pressure increased from P_2 back to P_1 as shown in the diagram. Which of the following statements are correct? Select two answers.

- (A) The area A represents the energy that is lost by the gas in this cycle.
- (B) The area A + D represents the “+” work done on the gas during the first compression.
- (C) The area D represents the “+” work done on the gas during the final expansion.
- (D) There was no energy lost or gained by the gas in this cycle.

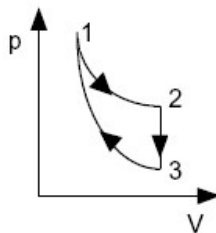
59. **Multiple Correct.** One end of a metal rod of length L and cross-sectional area A is held at a constant temperature T_1 . The other end is held at a constant T_2 . Which of the statements about the amount of heat transferred through the rod per unit time are true? Select two answers.

- (A) The rate of heat transfer is proportional to A .
- (B) The rate of heat transfer is proportional to $1/(T_1 - T_2)$.
- (C) The rate of heat transfer is proportional to L .
- (D) The rate of heat transfer is proportional to $(T_1 - T_2)$.

60. On all of the pV diagrams shown below the lighter curve represents isothermal process, a process for which the temperature remains constant. Which dark curve best represents an adiabatic process?



61. Three processes compose a thermodynamic cycle shown in the accompanying pV diagram of an ideal gas.



Process 1→2 takes place at constant temperature (300 K). During this process 60 J of heat enters the system.
 Process 2→3 takes place at constant volume. During this process 40 J of heat leaves the system.
 Process 3→1 is adiabatic. T_3 is 275 K.

What is the change in internal energy of the system during process 3→1?

- (A) -40 J
- (B) -20 J
- (C) +20 J
- (D) +40 J